POTASSIUM STATUS IN A LIMESTONE VALLEY SOIL RECEIVING SURFACE APPLICATIONS OF POTASSIUM FERTILIZER

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Abstract

A field study conducted in North Alabama to evaluate cotton (*Gossypium hirsutum*) response to long-term applications of K fertilizer was sampled to evaluate the potential downward movement of applied K and the effects of applied K on the forms of soil K. The field test was initiated in the fall of 1986. Potassium was applied to a Dewey silt loam (Typic Paleudult) at rates of 0, 60, 120 and 180 lb K_2O acre^{-1} for the first three years of the study. No K fertilizer was applied during the fourth year of the study (1990). After the fourth year of the test, half of the plots were left in residual. The experiment had a split plot design with four replications. During 1987-1989, two varieties were compared (Stoneville 825 and Deltapine 50) and these served as whole plots. During 1991-1997, only one variety was evaluated and annual versus residual K fertilization served as whole plots. Potassium treatments have been used as subplots throughout the test. Intensive soil sampling was conducted in the fall of 1989, 1993 and 1997. Analysis of soil samples collected at depths of 0-9, 9-15, 15-20, 20-25, and 25-30 inches showed that K fertilization increased the level of Mehlich 1, ammonium acetate and boiling nitric acid (nonexchangeable) extractable K in the surface 0-9 inch layer only. Ammonium acetate extracted higher amounts of K as compared to the Mehlich I extractant, but in 1994 both extracts gave similar correlation with lint yields. Quantity-Intensity (Q/I) relationships determined on surface samples collected in 1993 showed that the potential K buffer capacity of this Limestone Valley soil was not affected by the addition of K fertilizer. Exchangeable K determined using Q/I was lower as compared to ammonium acetate extractable K and was similar to values obtained using the Mehlich I extractant.

Introduction

Laboratory studies were conducted to evaluate the long term effects of K fertilization on the status of K in a Limestone Valley soil in North Alabama. This study was conducted by analyzing soil samples that were collected from a long-term field study that was initiated in the fall of 1986 on a Tennessee Valley soil in North Alabama that had been in alfalfa (*Medicago sativa* L.) production for five years. The objectives of this study were: 1) Evaluate the effects of long-term applications of K fertilizer on exchangeable and non-exchangeable K; 2) Evaluate the effects of K fertilization on the potential K buffer capacity of this Limestone Valley soil; and 3) Evaluate the potential downward movement of K resulting from long-term surface applications of K.

Materials and Methods

The field test sampled for this study was initiated in the fall of 1986 on a Dewey silt loam (clayey, kaolinitic, thermic Typic Paleudult) in North Alabama. Alfalfa had been produced on the test site for five years prior to the initiation of this test. Initially, the site had a "low" soil test rating for K according to the Auburn University Soil Testing Laboratory. Potassium was applied at rates of 0, 60, 120 and 180 lb K_2O acre^{-1}. Fertilizer was broadcast in the spring or split applied in the fall and spring (Table 1). Fall applied fertilizer was broadcast and the experimental area was turned with a moldboard plow to a depth of 8 to 10 inches. Spring applied K was broadcast prior to the final tillage operation in the spring. Initial treatments (1987-1989) also included two cotton varieties: 1) Deltapine 50 and 2) Stoneville 825. Plots were 25 feet long with six rows.

The experiment had a split-plot design with four replications. Varieties (1987-1989) were the whole plots. Potassium treatments were the subplots. The experiment was conducted using this treatment combination during the growing seasons of 1987, 1988 and 1989. In the fall of 1989 and spring of 1990, no K fertilizer was applied and soybeans (*Glycine max* (L) Merr.), variety "centennial" were grown in the entire experimental area. Potassium fertilization was resumed in the fall of 1990 with two major changes in the experiment: 1) only one variety was grown in the test and 2) half of the experimental plots received annual K fertilization treatments while the remaining plots were left in residual. Thus, during 1991-1997, annual and residual K fertilization were the whole plots and the initial K treatments served as subplots. Deltapine 50 was planted in 1991 and 1992 while Deltapine 51 was planted in 1993-1997. Yields were determined each year by mechanically picking the two center rows from each plot. Lint yield data were summarized by Mullins et al. (1998).

Since 1989, surface soil samples have been collected in the fall of most years for routine soil test analysis by the Auburn University Soil Testing Laboratory. In the fall of 1989, 1993 and 1997 intensive soil sampling was conduced in the residual (1989, 1993) and annual (1989, 1993, 1997) treatments to evaluate the profile distribution of K. Six, 1.25 inch diameter soil cores were collected from the center

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of each plot following harvest in the fall. Each core was subdivided into depth increments of 0-9, 9-15, 15-20, 20-25, and 25-30 inches. Samples from the same plot and depth were composited, air dried, and ground to pass a 10 mesh sieve. The samples were analyzed for Mehlich 1 (1989, 1993, 1997), 1 N ammonium acetate (1993, 1997) and boiling nitric acid (1993, 1997) extractable K.

Mehlich I extractable K was determined by extracting 5g subsamples of soil with 20 mL of the Mehlich I extracting solution (Isaac et al., 1983). Neutral 1 N ammonium acetate extractable K was determined by extracting 20 g subsamples of soil with 200 mL of neutral ammonium acetate (Kundsen et al., 1982). Boiling nitric acid extractable K was determined by gently boiling 2.5 g subsamples of soil with 25 mL of 1.0 N HNO_3 (Kundsen et al., 1982). Nonexchangeable K was calculated by subtracting the ammonium acetate extractable K from the nitric acid extractable K.

Surface samples collected in the fall of 1993 from annual treatments receiving 0, 60, 120, and 180 lb K_2O/acre were also subjected to evaluation of K quantity/intensity (Q/I) relationships. Duplicate subsamples of soil from each treatment with weights of 0.125, 0.25, 0.5, 1.00, 2.50, and 3.5 grams were extracted with 25 mL of extracting solution. The extracting solutions were: 0.002 M $Ca(Cl)_2$, 0.00025 M KCl, 0.0005 M KCl, 0.001 M KCl, 0.0015 M KCl, 0.002 M KCl, and 0.004 M KCl (all KCl extracting solutions were made using 0.002 M $Ca(Cl)_2$ as a background solution. Samples weighing 0.125 to 2.5 g were also extracted with the background 0.002 M $Ca(Cl)_2$ solution. The samples were placed on a reciprocating shaker for 20 h, centrifuged and filtered. Potassium concentrations were determined using flame emission. Calcium and magnesium concentrations were determined by inductively coupled argon plasma spectrophotometry. Activities of K, Ca and Mg and activity ratios $[^aK/(^aCa + {^aMg})^{0.05}]$ were calculated for each extract using the procedures outlined by Sparks (1980).

Results and Discussion

As expected annual K fertilization increased Mehlich I extractable, ammonium acetate extractable and nonexchangeable K in the plow layer of this soil (Table 2). Soil test ratings for the surface layer (using Mehlich I extractant) ranged from low (Adams et al., 1994) in the no K check treatment to high for the 180 lb K_2O/acre rate. Split and/or fall applications of K were not significantly different from corresponding treatments that received the same total K rate in the spring.

Ammonium acetate extractable and Mehlich I extractable K followed similar trends with respect to K rate, except that ammonium acetate consistently gave higher values as compared to the Mehlich I extractant (Table 2). Growing conditions resulted in the lack of a response to K in 1993 (Mullins et al., 1998), but a response to K was observed in 1994. During 1994 Mehlich I and ammonium acetate extractable K gave similar correlations with mean lint yields (Fig. 1). An interesting and somewhat surprising result was that for a given rate of applied K there was very little difference between the amount of extractable K measured in 1993 vs. 1997 for either Mehlich I or ammonium acetate.

Depth samples collected in the fall of 1989, 1993 and 1997 (1989 data not shown) revealed that K fertilization had increased ($P \leq 0.1$) Mehlich I (1989, 1993, 1997; Fig. 2 and 3), ammonium acetate (1993, 1997; Fig. 4 and 5) and boiling nitric acid (1993, 1997; nonexchangeable) extractable K in the plow layer of this soil. However, there were no significant differences for these forms of soil K at any depth below the plow layer (up to 30 inches deep). Similar results for Mehlich I extractable K have been found in cotton fields throughout the state of Alabama (Mitchell et al., 1992). These data show that after 10 annual applications of K fertilizer there was no detectable downward movement of K beneath the plow layer of this soil.

Quantity/Intensity

Typical Quantity/Intensity (Q/I) plots for the no K check treatment and the annual treatment receiving 120 lb K_2O/acre are illustrated in Fig. 6 and Fig. 7, respectively. Exchangeable K (K^o) determined using Q/I increased with K rate (Table 3). These values are similar to the 1993 levels of Mehlich I extractable K, but they are considerably lower than extractable K concentrations obtained using ammonium acetate. Lower values for K^o may be due to the amount of hydroxy iterlayered vermiculite in the clay fraction of this soil. Sparks and Liebhart (1981) also observed lower exchangeable K as compared to ammonium acetate.

Specifically adsorbed K (K_x) obtained using Q/I (Table 3) tended to increase with K rate, but these differences were not significant. Values for K_x were lower as compared to the level of nonexchangeable K as determined using boiling nitric acid (Table 2).

The equilibrium K activity ratio (AR_e^k) increased with K rate (Table 3; Fig. 6 vs. Fig. 7). Similar results have been observed by other researchers (Beckett, 1964; Sparks, 1980). Soils with $AR_e^k < 0.01$ are theorized to have preferentially held K at edge positions (Sparks and Liebhardt, 1981).

Potential K buffering capacity (PBC^k) averaged 49.8 (Table 3) and was not significantly affected by the addition of K fertilizer. Treatments used to develop the Q/I relationships had soil test ratings ranging from low to high based on the Auburn Soil Testing Laboratory (Adams et al., 1994). Thus we would conclude that for this soil and soils of similar mineralogy and K loading that K fertilization should have minimum effect on the potential K buffering capacity. The

PBC^k for this soil is much higher than the buffer capacity found by Sparks (1980) for a Typic Hapludult with a lower CEC. A high buffer capacity is thought to indicate less of a need for frequent additions of K fertilizer (LeRoux and Sumner, 1968).

Conclusions

Ten annual applications of K at rates ranging from 0 to 180 lb K_20/acre increased the exchangeable and nonexchangeable K in the plow layer of a limestone valley soil in North Alabama. There was no detectable downward movement of the applied K beneath the plow layer. Using the results of quantity/intensity relationships, it was concluded that K additions (six annual applications of K) and removal (check treatment) had not affected the potential K buffer capacity of this soil. Thus, we conclude that K fertilization of this limestone valley soil had minimal effect on the potential K buffer capacity.

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Table 1. Annual K fertilizer treatments. No K fertilizer was applied in the fall of 1989 and spring of 1990. Beginning in the fall of 1990, half of the experimental plots continued to receive annual K treatments.

Annual K Rates			Total Fertilizer K Applied	
Fall	Spring	Total	1987-1989	1991-1997
lb K_2O/acre				
0	0	0	0	0
0	60	60	180	420
0	120	120	360	840
0	180	180	540	1260
60	60	120	360	840
90	90	180	540	1260
120	0	120	360	840

Table 2. Effect of K fertilizer treatments on Mehlich 1, ammonium acetate and non-exchangeable (Non-Ex) K in the plow layer of a Limestone Valley soil as affected by annual rates of K fertilizer.

Annual K Rates			Mehlich 1		NH_4OAc		Non-Ex
Fall	Spring	Total	1993	1997	1993	1997	1993
lb K_2O/acre			lb/acre				
0	0	0	118	127	220	201	461
0	60	60	136	162	278	240	492
0	120	120	192	197	334	326	564
0	180	180	260	261	458	422	650
60	60	120	224	209	396	268	572
90	90	180	224	229	370	358	614
120	0	120	206	193	312	288	640
$LSD_{(0.10)}$			30	24	56	127	93

Table 3. Results of quantity/intensity evaluation of soil K: exchangeable K (K^o); specifically adsorbed K (K^x); equilibrium activity ratio (AR_e^k); and potential K buffer capacity (PBC^k) for the plow layer of the limestone valley soil in the fall of 1993.

Annual Rates					
Fall	Spring	K^o	K^x	AR_e^k	PBC^k
lb K_2O/acre		mg K kg^{-1}			
0	0	36	153	0.00168	52.4
0	60	52	170	0.00329	45.4
0	120	72	196	0.00311	57.2
0	180	110	257	0.0054	44.0
$LSD_{(0.05)}$		16	NS	0.00105	NS

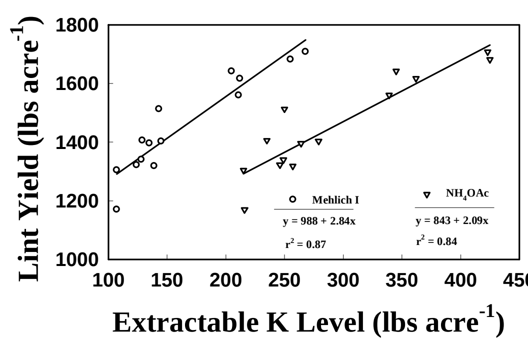

Fig. 1. Relationship between lint yields and the level of ammonium acetate and Mehlich 1 extractable K in 1994.

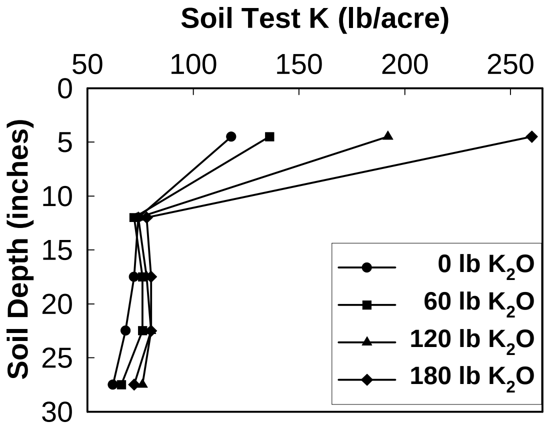

Fig. 2. Mehlich 1 extractable K with depth for the annual treatments in the fall of 1993.

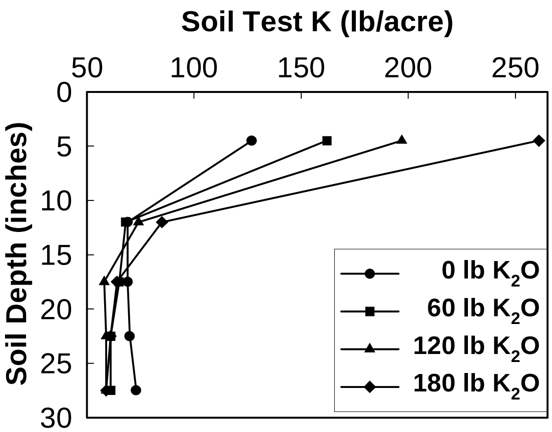

Fig. 3. Mehlich 1 extractable K with depth in the annual treatments in the fall of 1997.

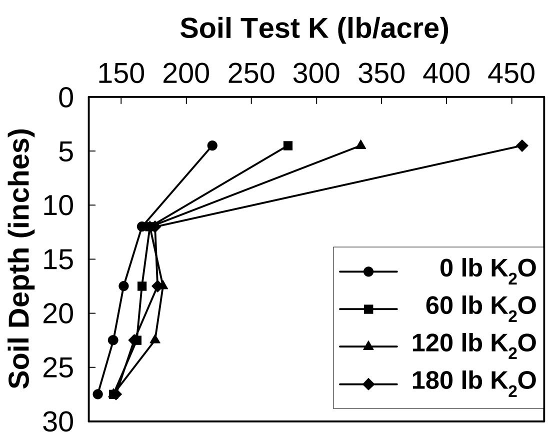

Fig. 4. Ammonium acetate extractable K with depth in the annual treatments in the fall of 1993.

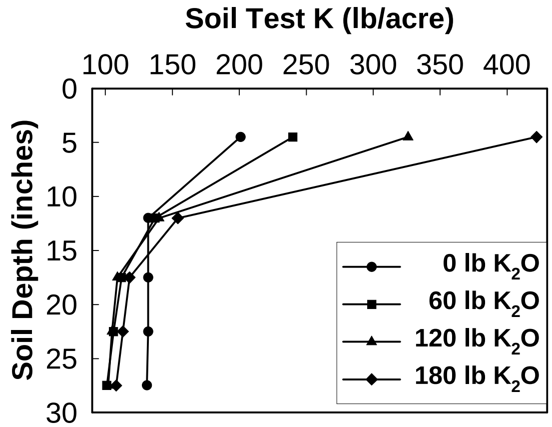

Fig. 5. Ammonium acetate extractable K with depth in the annual treatments in the fall of 1997.

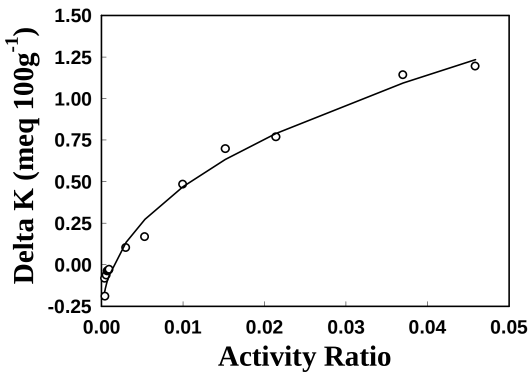

Fig. 6. Quantity/Intensity plot for K in the no K check treatment. Samples were collected in the fall of 1993.

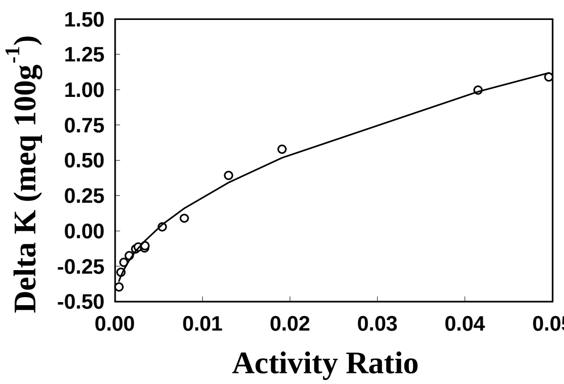

Fig. 7. Quantity/Intensity plot for K in the annual treatment receiving 120 lb K_2O/acre. Samples were collected in the fall of 1993.